SIGNAL PROCESSING APPARATUS AND METHOD THEREOF

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to a signal processing apparatus and method for processing an image signal of an image pickup apparatus such as a digital camera or the like.

Related Background Art

INS B1 Fig. 2 shows a construction of a conventional signal processing apparatus using image pickup devices of the complementary color system. Color filters of four colors of Mg (magenta), G (green), Cy (cyan), and Ye (yellow) as shown in Fig. 3 are adhered to the image pickup devices every device in order. An output signal from the image pickup device is transmitted through an OB (Optical Black) circuit 201, an individual difference variation correction circuit (pixel gain circuit) 202, WB (White Balance) circuit 203, and an offset circuit 204 and separately supplied to a luminance signal formation processing system and a chroma signal formation processing system.

In the luminance signal formation processing system, a gain level difference which is caused by the color filters is removed by a low pass filter (notch circuit) 215 and a clamping process is performed to a luminance signal by a Y clamp circuit 216.

Subsequently, an edge emphasis is performed by an APC (aperture) circuit 217. A level correction by color difference signals is performed by a Y compensation circuit (Ycomp circuit, luminance signal compensation circuit) 218. Thus, the luminance signal becomes a Yh luminance signal of 8 bits by a Y gamma (Y-Gamma, luminance signal gamma correction) circuit 219 having conversion characteristics as shown by a curve 502 in Fig. 5.

In the chroma signal formation processing system, the signal is interpolated by a color interpolation circuit 205 as if there were values in all pixels of four colors. A conversion of (the complementary colors → pure colors → color difference) is performed by a color matrix circuit (color conversion circuit) 206. A subtle correction of a chroma signal is performed by a linear clip matrix circuit 207. Subsequently, a gain of chroma signal in a saturation luminance area is suppressed by a C-SUP (chroma suppression) circuit 208. A band of the chroma signal is limited by a low pass filter 209. After that, a saturation is adjusted by a chroma gain circuit 210. Thereafter, the chroma signal is again converted into RGB signals by a matrix circuit 211 by a low band Yℓ signal and the color difference signals.

The low band RGB signals become RGB (red, green, blue) signals of 8 bits by a C gamma (chroma signal

gamma correction) circuit 213 having the conversion characteristics as shown by the curve 502 in Fig. 5. Subsequently, the RGB signals are converted into color difference signals Cr and Cb by a color conversion circuit 214.

An image signal is formed by the Yh signal from the luminance signal formation processing system and the Cr and Cb signals from the chroma signal formation processing system.

INS B2> However, when the luminance signal and the chroma signal are gamma converted into the signal of the same number of bits as in the above conventional technique, the following problems occur.

INS B3> Generally, each of RGB of an output range of a monitor as an output apparatus consists of 8 bits and there are gamma characteristics as shown by a curve 401 in Fig. 4. An output of the camera is a linear signal in which, for example, each of RGB consists of 11 bits. It is, therefore, necessary to non-linearly compress (gamma conversion) the camera output to the signal of the number of bits of the output apparatus in accordance with the characteristics of the monitor.

INS B4> cont Therefore, although the linear conversion of the luminance signal is preferable to prevent a deterioration of the hue, when the linear conversion is performed, an image becomes a dark image due to an influence by the gamma characteristics of the monitor.

To accurately reconstruct the gradations of the luminance, therefore, a reverse gamma conversion of the monitor characteristics as shown by a curve 402 in Fig. 4 (a curve 504 in Fig. 5) is performed. Although there is a slight deviation of the hue, the accurate gradation reconstruction of the luminance is held. If there is such a gamma curve, however, the image becomes an image which lacks a contrast in a middle luminance area of a main object.

B4 wml

INS B5 Hitherto, therefore, a gamma curve which can enhance a contrast of a draw area (middle luminance area) of the main object as shown by the curve 502 in Fig. 5 is used or a plurality of gamma curves according to the application are selectively used in accordance with a mode. In case of using the data of the curve as shown by the curve 502 in order to improve the contrast of the main object, it is necessary to further reduce the gradations in the low luminance area or high luminance area by an increased amount of the contrast in the middle luminance area. In this case, as shown in Fig. 5, particularly, in a high luminance and high saturation area of the chroma signal, an output signal difference between R and G in an output of the 8-bit C gamma circuit 213 shown in Fig. 5(a) is smaller than an output signal difference between R and G of the 8-bit C gamma circuit at the timing before the gradations of the middle luminance area in Fig. 5(c) are increased,

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the saturation is deteriorated, and the output signal difference between B and G is not largely changed, so that the hue is remarkably deviated. There are, consequently, such drawbacks that the color reconstruction of the high luminance area of the image after the gamma conversion deteriorates, the image is likely to be white skipped, and a discoloration occurs.

INS B6 An example of the conversion of the chroma signal in case of the gamma system when the conventional 8-bit C gamma curve 502 is used will be mentioned hereinbelow.

<1> 8-bit C-gamma

(a) Before gamma (11-bit RGB)

R = 1400

G = 1100

B = 400

(b) After gamma (8-bit RGB)

R = 236

G = 228

B = 140

Yh = 0.3R + 0.59G + 0.11B = 221

(c) RGB-YCrCb conversion

Yℓ = 0.3R + 0.59G + 0.11B = 221

Cr = R - Y = 15

Cb = B - Y = -81

(d) MIX with Yh signal on the output apparatus side

Yh = 220

$$R = Cr + Yh = 235$$

$$B = Cb + Yh = 139$$

$$G = (Yh - 0.3R - 0.11B)/0.59$$
$$= 212$$

A ratio of the level differences among the signals of RGB remarkably differs as compared with that of the signals before the gamma conversion (refer to Fig. 5(a)). Thus, the image becomes a picture whose hue changes and which is white skipped.

SUMMARY OF THE INVENTION

The invention is made in consideration of the above drawbacks and it is an object of the invention to provide a signal processing apparatus in which a color crush in the high luminance area of the image after the gamma conversion can be fairly reduced and the white skip of the image and the discoloration are remarkably improved.

To accomplish the above object, according to an aspect of an embodiment of the invention, there is provided a signal processing apparatus which can output a chroma signal of m bits as a chroma signal of n bits by an output apparatus, comprising: a gamma converting unit for gamma converting the chroma signal of m bits into a chroma signal of k bits; a color converting unit for converting the chroma signal of k bits obtained by the gamma converting unit into a signal of k bits

showing a brightness and a color tone; and bit converting unit for converting the signal of k bits showing the brightness and color tone obtained by the color converting unit into a signal of n bits showing a brightness and a color tone, wherein $m > n = k + 1$.

According to another aspect of the invention, there is provided a signal processing method which can output a chroma signal of m bits as a chroma signal of n bits by an output apparatus, comprising: a gamma converting step of gamma converting the chroma signal of m bits into a chroma signal of k bits; a color converting step of converting the chroma signal of k bits obtained in the gamma converting step into a signal of k bits showing a brightness and a color tone; and a bit converting step of converting the signal of k bits showing the brightness and color tone obtained in the color converting step into a signal of n bits showing a brightness and a color tone, wherein $m > n = k + 1$.

The above and other objects and features of the present invention will become apparent from the following detailed description and the appended claims with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a construction of a signal processing apparatus of an embodiment of

the invention;

Fig. 2 is a block diagram showing an example of a construction of a conventional signal processing apparatus;

Fig. 3 is a schematic diagram showing an example of complementary filters;

Fig. 4 is a graph showing gamma characteristics of a monitor as an output apparatus;

Fig. 5 is a graph showing a curve for performing each gamma converting process;

Fig. 6 is a graph showing a conversion curve of a bit adjustment circuit 120; and

Fig. 7 is a diagram showing an example of a conversion from chroma signals (RGB) to chromaticity signals (U, V).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the invention will now be described in detail hereinbelow with reference to the drawings.

Fig. 1 shows a circuit construction of a signal processing apparatus according to an embodiment of the invention.

INS B7 West

A black component is removed from a complementary signal (MgCyYe) from image pickup devices (not shown) by an OB (Optical Black) circuit 101 and a variation of the image pickup devices is corrected by a pixel gain

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circuit 102. After that, a white balance is corrected by a WB (White Balance) circuit 103 and a predetermined amount of offset is added by an offset circuit 104. An output signal of the offset circuit 104 is separately inputted to the luminance signal formation processing system and chroma signal formation processing system.

In the luminance signal formation processing system, a color filter level difference is removed by a notch filter (Y-LPF) circuit 115, a clamping process is performed to the luminance signal by a Y clamp circuit 116, and an edge is emphasized by an APC (aperture) circuit 117. An output signal of the APC circuit 117 is corrected by a Y compensation circuit 118 by the color difference signals. A gamma correction is performed by a Y gamma circuit 119 by using the C gamma curve 504 of 8 bits in Fig. 5, so that the signal becomes the Yh signal (luminance signal) of 8 bits.

In the chroma signal formation processing system, the dropped pixels of all of four colors are interpolated by a color interpolation circuit 105 and the signal is converted into the complementary colors (MgCyYe) → pure colors (RGB) → luminance color difference ($Y\ell$,R - Y,B - Y) signals by a color matrix circuit 106. After a subtle color correction was performed by a linear clip matrix circuit 107, a color suppression of a saturation area is performed by a C-SUP (chroma suppression) circuit 108. An output of the

C-SUP circuit 108 is band limited by a low pass filter circuit 109.

INS B8> The R-Y and B-Y color difference signals (±11 bits) which were band limited by the low pass filter circuit 109 are sent to a chroma gain circuit 110 and saturations are adjusted. The signals again become the RGB signals (11 bits) by a matrix circuit 111 by using an output signal from the chroma gain circuit 110 and the low band luminance signal $Y\ell$. An output of the matrix circuit 111 is gamma converted by a C gamma circuit 113.

INS B9> In the embodiment, an output range of the C gamma circuit 113 is set to 9 bits, thereby increasing a gradient of a gamma curve in a luminance area at a predetermined level or higher. An output range of the Y gamma circuit 119 is set to 8 bits. Output signals (RGB, 9 bits) of the C gamma circuit 113 are converted into YCrCb (CrCb = ±8 bits (c9)) signals by a color conversion circuit 114 and adjusted to the signals of the number of bits (CrCb = ±7 bits (c8)) of the output apparatus such as a monitor or the like by a bit adjustment circuit 120. (The luminance signal $Y\ell$ which is formed by the color conversion circuit 114 is not outputted to the output apparatus.)

INS B10> Cont The RGB signals set to 8 bits (c9) are formed by using the Yh signal set to 8 bits from the luminance signal formation processing system and the CrCb signals

B10 Cont set to ±7 bits (c8) from the chroma signal formation processing system and outputted to the output apparatus such as a monitor or the like.

INS B11 An effect of the improvement of the color gradation reconstruction which is obtained by increasing the number of output bits of the C gamma circuit 113 as a main component element of the embodiment will be described hereinbelow.

INS B12 In the embodiment, the number of bits of the gamma conversion of the chroma signal is set to be larger than that of the luminance gamma conversion, thereby preventing a deterioration of the color gradations. A curve 503 in Fig. 5 shows a gamma curve of 9 bits and a gradient of the curve in a range from the middle luminance area to the high luminance area can be increased than that of the 8-bit gamma curve 502 because the maximum output is larger than that of the 8-bit gamma. Therefore, a level difference among the RGB signals after the gamma conversion does not change to a level larger than that of 8 bits of C gamma. Thus, the saturation in the high luminance area is hardly deteriorated (refer to Fig. 5(b)).

The 9-bit RGB signals after the gamma conversion are subjected to an 8-bit limitation of a non-linear process by the bit adjustment circuit 120. In this case, although the CrCb signals are bit limited to the 9-bit (±8 bits (c9)) signals, since the color

difference signals do not become extremely large even if the number of bits of the RGB signals is larger than 8, the color reconstruction is not deteriorated.

Fig. 6 is a diagram showing input (±8 bits (c9)) - output (±7 bits (c8)) characteristics of the bit adjustment circuit 120. When either the Cr signal or the Cb signal enters a non-linear area at a predetermined input level or higher and is gain corrected, the other color difference signal is also multiplied by the same gain, thereby preventing the hue from changing. When both Cr and Cb signals enter the non-linear area and are gain corrected, those two gains are compared. The smaller gain is selected and multiplied to Cr and Cb.

INS B13 An example of the gamma conversion using the output characteristics of RGB 9 bits according to the embodiment will be mentioned hereinbelow.

(a) Before gamma (11-bit RGB)

R = 1400

G = 1100

B = 400

(b) After gamma (9-bit RGB)

R = 239

G = 242

B = 140

(c) RGB-YCrCb conversion

$Y\ell = 0.3R + 0.59G + 0.11B$

= 239

Cr = R - Y = 30

Cb = B - Y = -99

(d) Bit adjustment (±8 bits → ±7 bits)

~~Cr = 30~~

Cb = -99

(There is no change in the example because the input signal levels of the bit adjustment circuit lie within the linear areas.)

(e) MIX (synthesis) with Yh signal on the output apparatus side

Yh = 220

R = Cr + Yh

= 251

B = Cb + Yh

= 121

G = (Yh - 0.3R - 0.11B)/0.59

= 223

As mentioned above, the outputs of RGB which are obtained are based on

conversion by the 9-bit gamma curve 503

(R, G, B) = (251, 121, 223)

in response to

conversion by the 8-bit gamma curve 502

(R, G, B) = (235, 139, 212)

INS B14> Cont

The saturation in case of the C gamma curve 503 of 9 bits is stronger than that of the C gamma curve 502

B14 Cont of 8 bits, the deviation of the hue is also smaller, and a white skip of the color occurs less.

INS B15 According to the embodiment with the above construction, by setting the number of output bits of the gamma conversion of the chroma signal to a value larger than that of the luminance gamma conversion and by using the gamma curve which does not reduce the gradations of the high luminance area, a deterioration of the color gradation reconstruction of the reproduction image is prevented.

INS B16 For example, when the number of input bits of the output apparatus such as a monitor or the like is equal to 8, in the signal processing apparatus of the embodiment, the input of the Y gamma circuit is set to 11 bits, its output is set to 8 bits, the input of the C gamma circuit is set to 11 bits, and its output is set to 9 bits. By setting the output of the C gamma circuit to 9 bits as mentioned above, when the 8-bit gamma is used, the gradient in the luminance area at the saturated predetermined level or higher can be set to be larger, and the color crush can be fairly reduced.

INS B17 Cont To form the final RGB image signals by mixing with the output luminance signal Yh of the Y gamma circuit, the output signals (RGB, 9 bits) of the C gamma circuit are color converted into the YCrCb signals. The CrCb signals obtained by the color conversion are non-

B17 cont

linearly operated to the bit width (±7 bits) of the output apparatus in accordance with the bit width of the output apparatus. In the non-linear arithmetic operation, even if the RGB signals have the range of 9 bits, the color difference signals do not increase extremely so long as the saturation and the illuminance are not abnormally large. Even if the signals after the color difference conversion are non-linearly converted and the number of bits is reduced, a resultant picture is not adversely influenced. Therefore, if the C gamma curve as shown by the curve 503 in Fig. 5 is used, for example, the color reconstruction, white crush, and change in hue (discoloration) in the high luminance area are remarkably improved.

[Another embodiment]

INS B18 Although the CrCb conversion has been performed in the color conversion circuit 114 in the embodiment, YUV conversion can be also performed in accordance with a format of the output apparatus at the post stage. In this case, a chroma signal conversion is executed in the color conversion circuit 114 by using the following arithmetic operations.

$$Y = 0.2990 \times R + 0.5870 \times G + 0.1140 \times B$$

INS B19 (The converted Y signal is not actually outputted to the output apparatus.)

$$V = 0.5000 \times R - 0.4187 \times G - 0.0813 \times B$$

$$U = -0.1684 \times R - 0.3316 \times G + 0.5000 \times B$$

The chromaticity signals U and V obtained by the color conversion circuit 114 as shown in a conversion example of Fig. 7.

Ins B20 Even in case of performing the CrCb conversion in the color conversion circuit 114, if the maximum output of the C gamma circuit 113 is set lest the output exceeds ±7 bits (in the embodiment, it is sufficient to set the maximum output to 365 or less), such a construction that one upper bit is omitted and only eight lower bits are outputted can be obtained in the bit adjustment circuit 120. With respect to UV conversion, same process can be applied. According to such construction, a burden of processes in the bit adjustment circuit 120 at the post stage is reduced.